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Introduction to Frequently Asked Question About Climate Change and Why You Should Ask Them

Global Climate Change, at times referred to as global warming, is a phenomenon involving interrelated changes among the various parts of the earth system: atmosphere, biosphere, hydrosphere and lithosphere. As such, an understanding of the subject requires integrating knowledge from very nearly all of the traditional sciences as well as some newer ones such as atmospheric science, biogeochemistry and climate modeling. No one can expect to have a completely comprehensive scientific grasp of the entire subject, but I believe that almost everyone can develop an informed position on it. To this end, I have assembled a set of frequently asked questions and answers with the hope that it may aid those who are interested in obtaining the necessary knowledge.

The phrase "global climate change" itself is loaded with meaning. Global refers not only to a region or even a continent, but also to the whole Earth system. Climate on the other hand encompasses the long time average of a specific region’s weather. It references an average value of temperature, rainfall, soil moisture, etc. for a place, such as Houston, Texas or southwest Iowa. Global climate must therefore describe a single combined average of local and regional climate values. In order to specify a global temperature average, one must gather and analyze temperature data from stations representing every climate region on Earth. Change in the global climate does not mean simply a deviation from the “average” or seasonal changes in weather. It does not even mean localized deviations in climate, but rather an actual shift in the averages of climate parameters over the entire globe. An understanding of global climate change can be viewed as four cumulative steps:

1. Detecting, over time, a definite trend in the direction of change in the global climate: Is it really happening?”
2. Attributing climate change to anthropogenic (human induced) or natural causes: Who and what are the real causes of climate change?
3. Modeling climate to determine the degree and effect of future climate change: What can we expect?

4. Responding to climate change predictions: What if anything can be done about it?

Q1: Is Global Climate Change Really Happening?
Detecting, over time, a definite trend in the direction of change in the global climate: Is it really happening?

Detecting, over time, a definite trend in the direction of change in the global climate: Is it really happening?

Short answer

The Synthesis Report based on the fourth assessment of the Intergovernmental Panel on Climate Change (2007) reports, “Warming of the climate system is unequivocal.”

Detailed answer

This conclusion is now evident from observations of atmospheric and oceanic temperature. Global surface temperature, includes both surface air temperature measurements at terrestrial weather stations and sea surface temperature measurements from ships and satellites. Temperatures from each station are averaged over day and night as well as throughout the seasons of the year. The results show a global average surface temperature increase of 1.4°F (0.78°C) since 1905, with about 1.1°F (0.61°C) of the increase occurring since the mid 1970’s. Nine of the ten warmest years ever recorded occurred during the past decade. The average increase in sea surface temperatures has been about half that of air temperatures.

Other changes in climate have been observed such as changing precipitation patterns, drought and floods, storm intensity, polar and glacial ice melt and seasonal disruptions of terrestrial ecosystems. Predicting these regional changes with climate models is difficult and incomplete, so questions remain as to how correlated these changes are with respect to increasing greenhouse gases in the atmosphere.

Rain and snow patterns have shifted during the past century. Precipitation has increased in eastern parts of North and South America, northern Europe

and central Asia but has declined in the Mediterranean, parts of Africa and southern Asia.

There is good evidence for an increased intensity of tropical cyclonic storms in the north Atlantic with less convincing evidence elsewhere. There is no clear indication of an increased frequency of tropical cyclones.

A decrease in the extent of polar ice and snow is evident. Late summer Arctic sea ice is shrinking at the rate of about 8% per year and may result in an ice clear summer Arctic Ocean in 20 to 30 years.

Melting of Greenland's ice sheet is speeding up. NASA satellite data show the melting rate has accelerated since 2004. Estimated monthly changes in the mass of Greenland's ice sheet suggest it is melting at a rate of about 239 cubic kilometers (57.3 cubic miles) per year. There is no clear evidence that this rate will be maintained or that the ice sheet will stabilize. Since Greenland ice contains about as much water as the Gulf of Mexico or something of the order of 600,000 cubic miles, there appears to be little danger of a complete meltdown in the next century. Other ice systems are also melting at an accelerating rate. This loss of glacier ice is evident for most of the world's glaciers. Perhaps the most dramatic glacier withdrawal has been in the Alps, where it has occurred in full view of residents and tourists. An 1859 etching of the Rhone glacier in the Canton of Valais, Switzerland shows the ice filling the valley. In 2001 the glacier was nearly out of sight, 2.5 km (1.6 miles) distant and 450 meters (1500 feet) higher.

Sea level has been rising about 1 to 2 centimeters per decade due to the water gained from the melting of ice caps, ice fields, and mountain glaciers in addition to the thermal expansion of ocean water. Recent studies indicate that about 12% of this rise comes from ice shedding from the Greenland and Antarctica ice sheets. The remaining 88% is due to the expansion of warming sea water and melting from mountain glaciers and other ice caps. This rise is consistent with the general warming of the Earth system.

Because climate is quite a chaotic phenomenon involving a multitude of effects, not every year will be warmer than the last or will other weather events such as hurricane intensity or ice melting increase annually in a smooth fashion. However the modeled trends are certainly consistent with

what might be expected from the increase in the observed atmospheric greenhouse warming. For example, while some regions of Antarctica, particularly the peninsula that stretches toward South America, have warmed in recent years, weather stations in other regions of Antarctica, including the one at the South Pole, have recorded a cooling trend. Recent studies however now show that there is warming across the whole continent--stronger in winter and spring but it is there in all seasons. "These data indicate the eastern region of the continent, which is larger and colder than the western portion, is warming at 0.1C per decade, while the west is warming at 0.17C per decade – faster even than the global average.

Q2: What are the Causes of Global Climate Change?
What are the real causes of climate change?

Attributing climate change to anthropogenic or natural causes: Who and what are the real causes of climate change?

Short answer

A general consensus exists that the climate is changing and the globe is warming. However, there remain questions with some people as to the cause. Unfortunately these questions have sometimes descended into a debate with one side claiming natural causation and the other side asserting manmade or anthropogenic cause. As is the case in most complicated issues, the answer lies somewhere in the middle. When asked, “Is climate change due to natural cycles or greenhouse gases?” the answer is “Yes.” Both natural and human factors are driving climate change.

Detailed answer

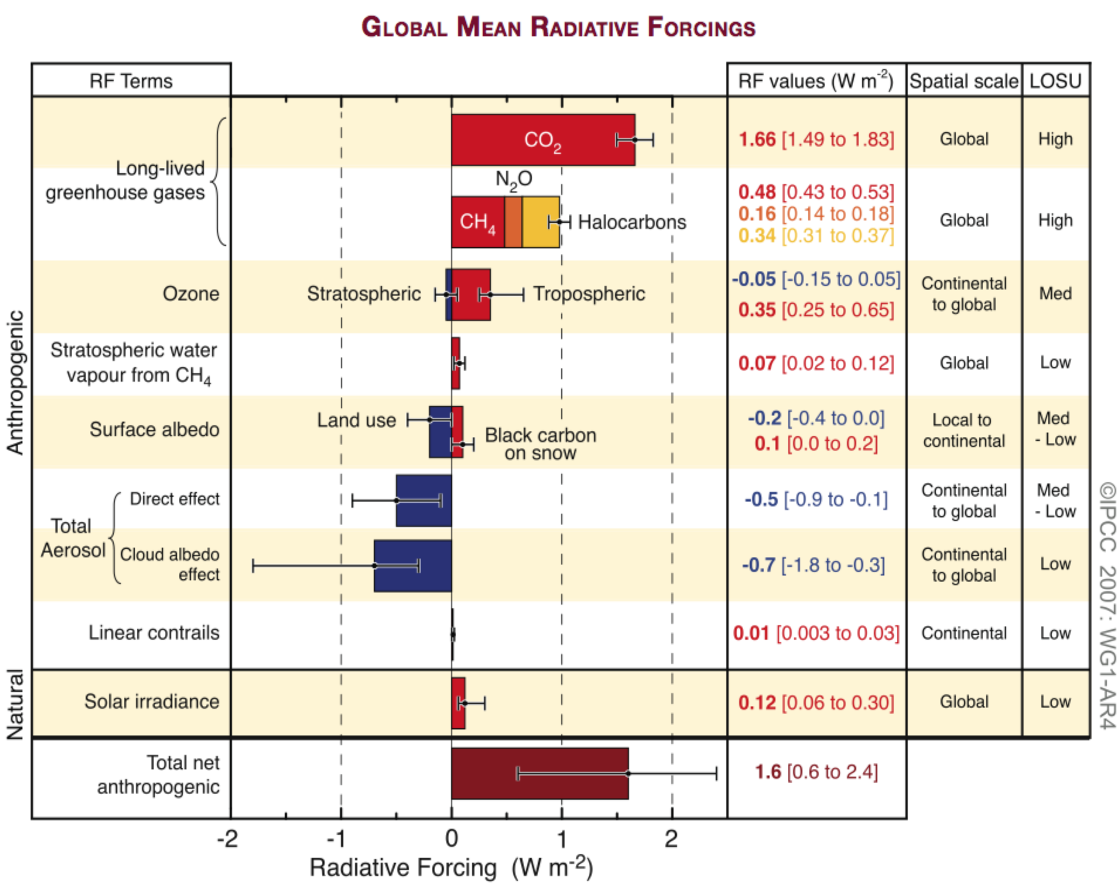
On a geological time scale, the climate has changed many times in the past, even before the presence of humans. These changes were obviously naturally caused because man had not yet evolved. A well-known example of climate is the occurrence of ice ages. The earliest well-documented ice age occurred from 850 million to 630 million years ago. The best-characterized ice ages are the most recent ones. These have been detected for at least the past 600,000 years. A geologic history of these ice events is preserved in the ice sheet covering Antarctica and Greenland. It has been uncovered over the past several years by scientists who have cored deeply into the ice and have deciphered the temperature and atmospheric composition records frozen in the ice. The temperature at which the ice originally formed can be obtained from an interpretation of the measured ratio of the stable isotopes of oxygen in the molecules of water forming the ice. The atmospheric gas composition is taken from air bubbles trapped in the ice at the time of formation.

The 100,000 year major cycle of the ice ages and some variations within the cycles agree very well with predicted periodic relationships between the Earth’s and the sun’s orbits (generally referred to as the Milankovitch cycles). These are very long term changes. They do not significantly affect the climate change that is currently happening with much greater rapidity.

The Earth receives energy from the sun and in turn radiates energy back into space. When these two energies are equal, a stable temperature of the Earth is achieved. This temperature can be calculated from basic physics and is equal to about 0°F (-18°C). This “thermal equilibrium temperature” is obviously not that of the surface of the Earth which has an average value of about 59°F (15°). The difference between these temperatures is due primarily to the natural greenhouse gas concentrations in the atmosphere. The influence of the “natural greenhouse gases”, mainly water and some carbon dioxide, moderates the Earth’s climate and makes life possible. If the Earth had no naturally occurring atmospheric greenhouse gases, the temperature of the surface of the Earth would equal the thermal equilibrium temperature.

The industrial revolution began to make major changes in manufacturing and transportation around the world. Beginning in Britain, industrialization spread through Europe and North America, eventually affecting the whole world. The development of steam power, fuelled by coal, and later transportation, beginning with the discovery of large deposits of oil, had enormous influence on the economic and social structure of the world. As the world accelerated in the production and transportation of manufactured goods, so the production and consumption of these fossil fuels grew. General prosperity and economic growth continued to increase, and so did the production of carbon dioxide, the combustion byproduct of industrial success. This carbon dioxide and other byproducts of human activities, e.g. deforestation, agricultural gases from rice fields and cows, and industrial nitrous oxide and chlorofluorocarbons added significant concentrations of greenhouse gases to the atmosphere. By 1990, over seven billion tons of carbon (equivalent to 26 tons of carbon dioxide) were being emitted into the atmosphere every year. Similar to the action of the naturally existing greenhouse gases, any additional greenhouse gases would lead to an increase in the surface temperature of the globe.

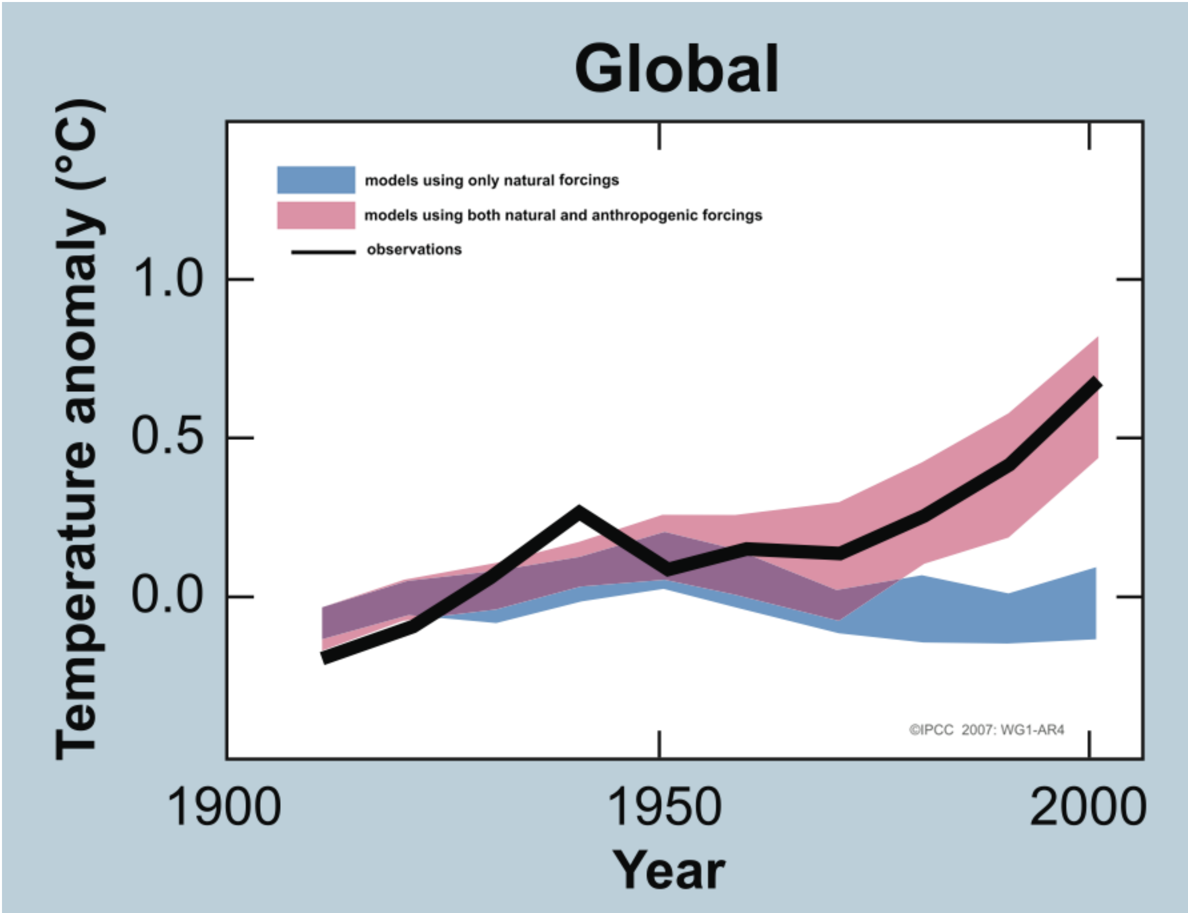
In addition to new greenhouse gases, other man made changes may be forcing climate change. Increases in near surface ozone from internal combustion engines, aerosols such as carbon black, mineral dust and aviation-induced exhaust are acting to raise the surface temperature. Other aerosols such as those formed from emitted sulfur compounds reflect sunlight and thus act to lower the surface temperature. The reduction of ozone in the stratosphere, production of sulfate, biomass burning and land use changes are acting to change the surface temperature. Transient natural events such as volcanic eruptions and cyclic effects such as small changes in solar energy also can cause both positive and negative temporary changes in the surface temperature.



Global mean radiative forcing terms divided into anthropogenic and natural causes. Blue bars indicate a negative or cooling effect on the

climate and red indicates a positive or heating effect. Greenhouse gases other than carbon dioxide are shown in a different colors which are all heating effects (IPCC, Working group 1, 2007).

[link] shows a listing of climate change forcing effects and their 90% confidence levels in 2005 for various agents and mechanisms. These forcings are given in units of Watts/meter squared, a commonly used unit of power measurement. These may be compared to 343 Watts/meter squared, the average amount of energy from the Sun that strikes the Earth's outer atmosphere. They are both natural and anthropogenic and are both positive and negative causing an increase or decrease change in temperature, respectively. Blue bars indicate a negative or cooling effect while red bars indicate a positive or heating effect. The greenhouse gases other than carbon dioxide (methane, nitrous oxide and halocarbons are shown together with different colors for each gas. LOSU represents the level of scientific understanding or confidence level. Volcanic aerosols contribute an additional form of natural forcing but it is not included because of the short lifetime of the effect.



Comparison between observed average global temperatures and corresponding modeled temperatures with and without anthropogenic climate forcings (IPCC, Working group 1, 2007).

A comparison of observed global-scale changes anthropogenic effects is presented in [link]. The decadal averages of observations are shown for the period 1906 to 2005 (black line). All temperatures are plotted relative to zero being defined as the corresponding average for the period from 1901 to 1950. The blue shaded band shows the 5% to 95% range for 19 simulations from 5 climate models using only the natural forcing effects due to solar activity and volcanoes. The red shaded band shows the 5% to 95% confidence range (common limits of confidence in the model calculations) for 58 different simulations from 14 climate models using both natural and anthropogenic forcings. These different simulations and the different

models are used by different scientific groups and represent different treatments of the Earth system. It is thus quite encouraging that model calculations are in major agreement with the assumption that global temperature change from 1900 to 2000 is due to both natural and anthropogenic effects, with anthropogenic effects being the major causes in its recent dramatic increase.

Q3: What can We Expect from Modelling Climate Change

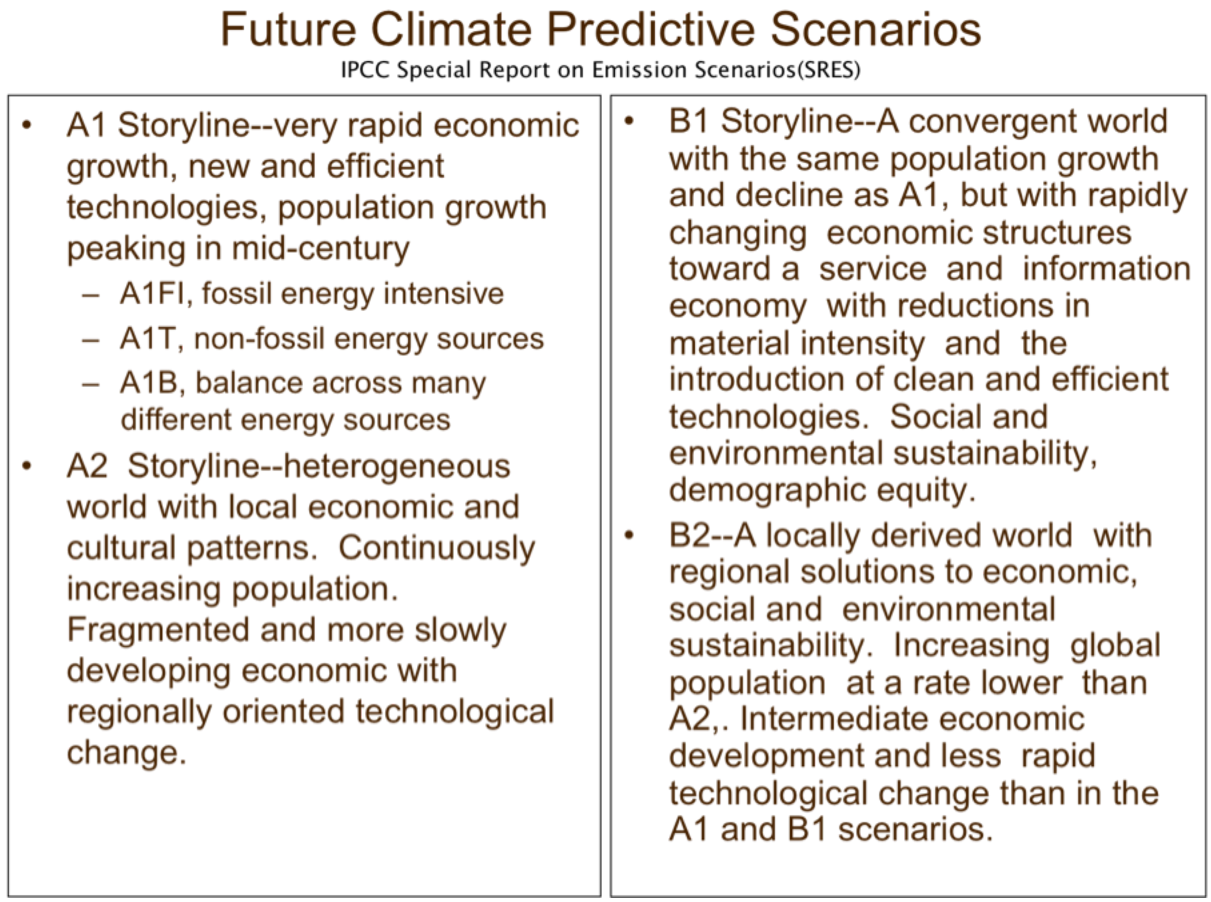
Modeling climate to determine the degree and effect of future climate change: What can we expect?

Short answer

The future global surface temperature and some other climate variables can be modeled with reasonable confidence for various scenarios for the future energy policy of the globe. These results are only as good as our ability to predict the actual energy consumption patterns of the whole world.

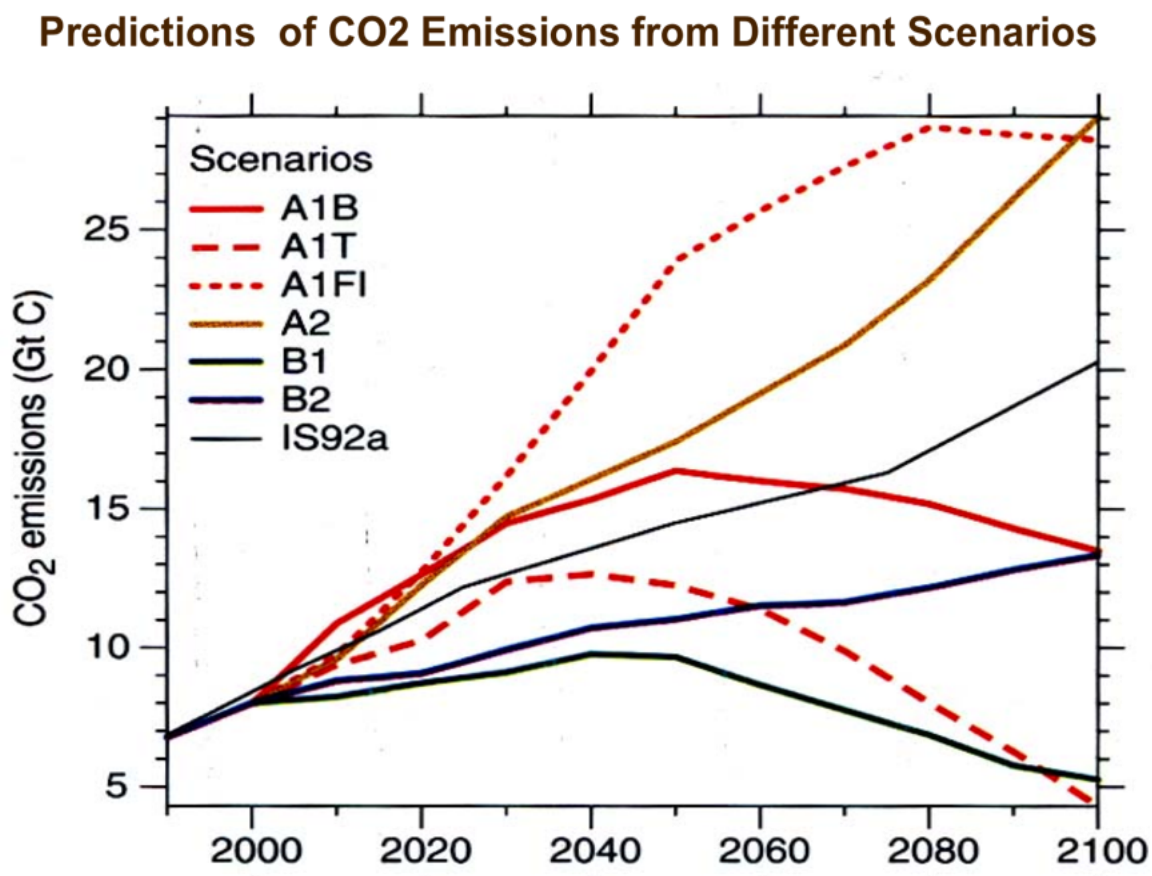
Detailed answer

Predicting the future with any real precision is virtually impossible. Future climate change depends on several human activities, the most important of which are the use of fossil fuels for energy and continued land use change in the form of new urban communities or reductions of forest areas. The current best way to approach a prediction of future climate is to develop a series of plausible scenarios of future human activity and then run simulations using a multi-model approach to obtain average climate outcomes for each. The results will be an array of different climate futures that can provide a basis for choosing how much climate change we wish to tolerate and what mitigation and life style changes will be necessary to achieve that end.



IPCC adopted scenarios of the Earth's energy future for the purpose of predicting the resultant climates

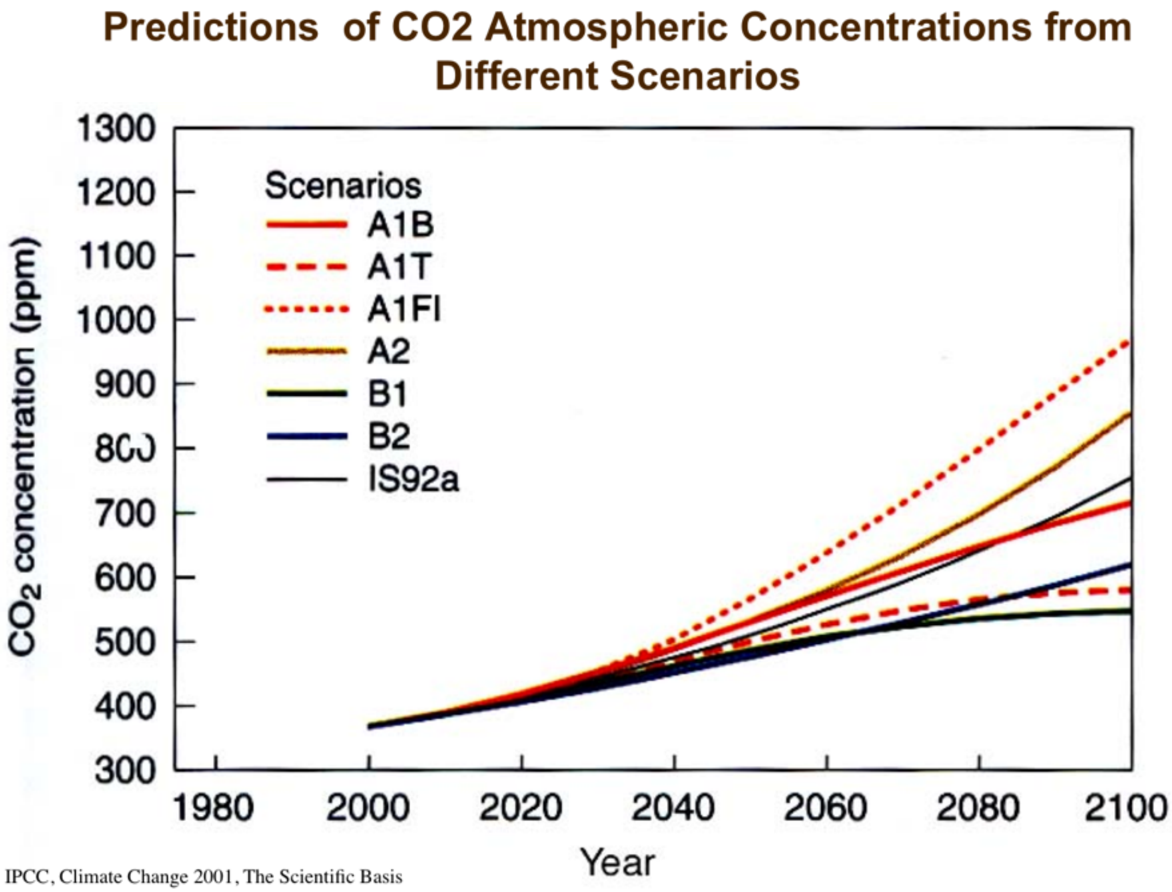
Several scenarios have been proposed for the global future. The IPCC "Special Report on Emissions Scenarios" (2000) presents six scenarios for the future. These are named A1B, A1F1, A1T, A2, B1 and B2 and are briefly described in [link]. The carbon emission predictions derived from these scenarios are compared over the next century in [link]. The carbon dioxide (CO_2) emission values are in GtC (Gigatons carbon) per year. A gigaton of carbon refers to only the weight of carbon in the carbon dioxide emissions. The amount of carbon dioxide can be obtained by multiplying the amount of carbon by the ratio of the molecular weights of carbon dioxide to carbon (44/12 = 3.67). Thus the value of the current emission (7 GtC) is really 25.7 Gt carbon dioxide.



IPCC, Climate Change 2001, The Scientific Basis

The development of carbon emission scenarios over the next century.

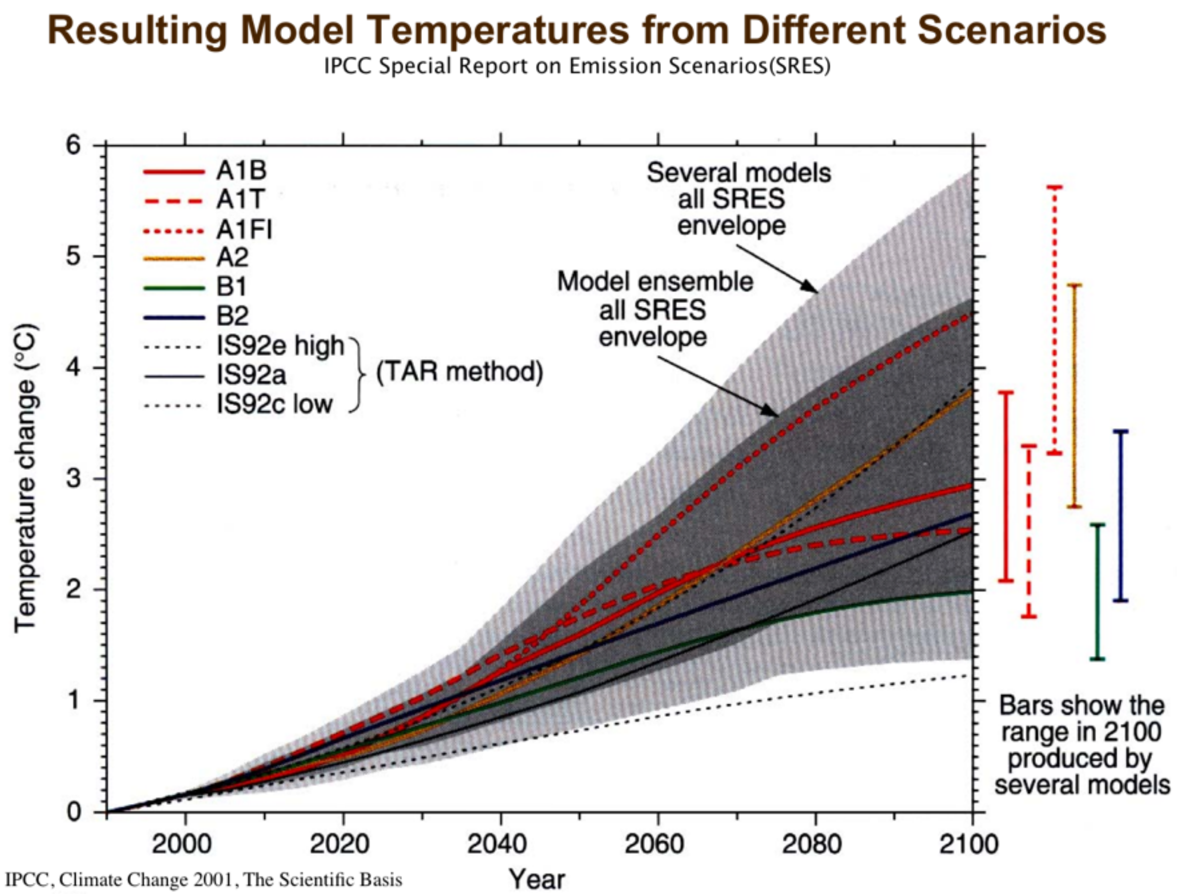
The corresponding changes in the concentration of atmospheric carbon dioxide are depicted in [link].



Values over the next century of predicted atmospheric concentrations of carbon dioxide.

The most optimistic emission curtailments are found in both A1T and B2. A1T indicates early increases in carbon emissions followed by a steady decline as population peaks and declines and as fossil fuel is replaced by renewable energy sources. B2 stresses moderation on all fronts–social, economic and environmental. The most distressing scenarios for carbon emissions are A1F1, which maintains intensive fossil energy, and A2, which is probably the closest scenario to “business as usual”. The last two scenarios, A1B and B1, end up the century with intermediate carbon emissions. Because A1B peaks and is decreasing as 2100 approaches, it has greater promise of even lower values in the following century. Yet, B1 is a very probably the most realistic approximation of the best that can be expected for the world. Each of these scenarios has been subject to multiple

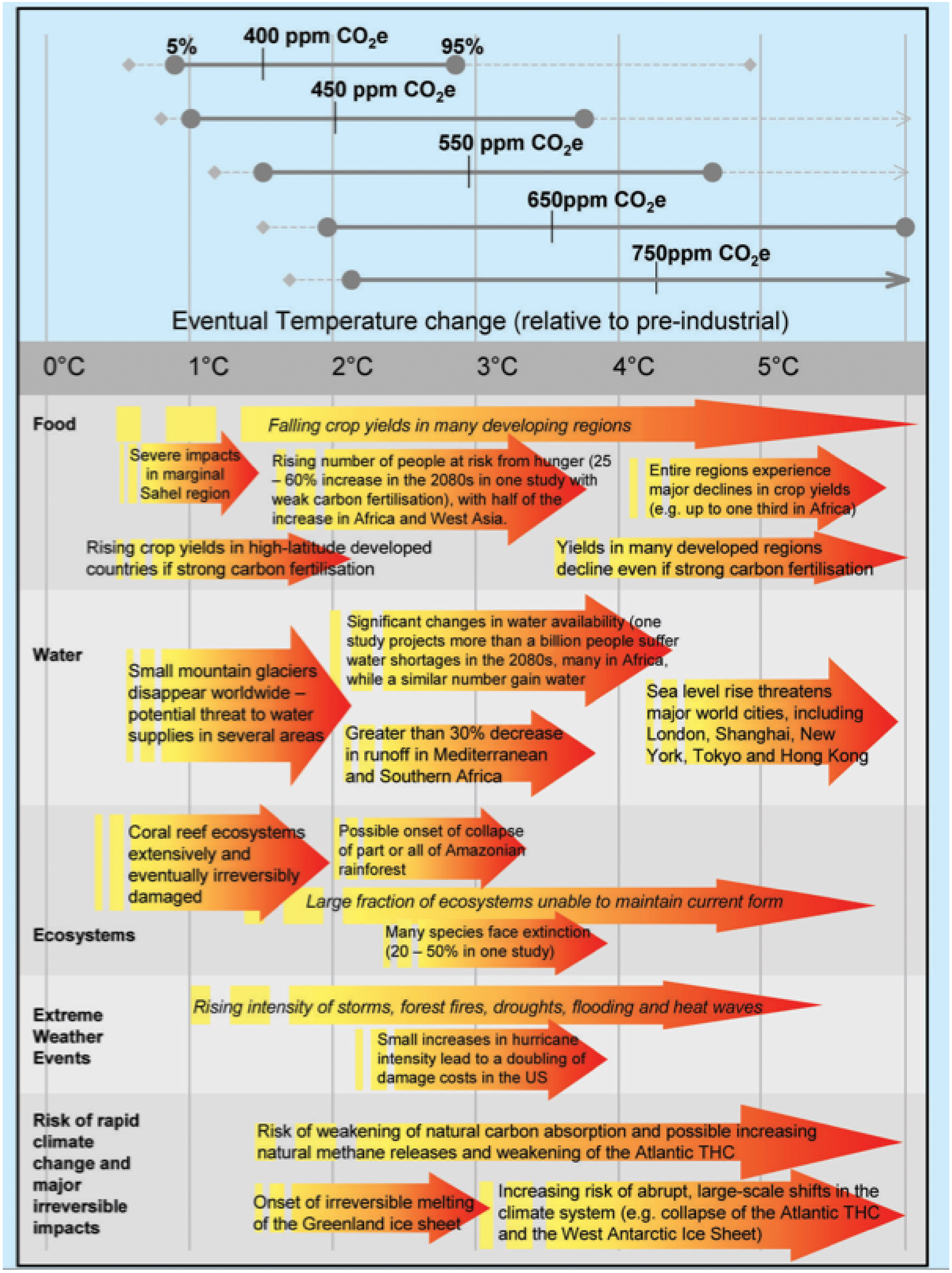
computer simulations and the best estimated average global surface temperature increase (°C) as well as the statistical error bar (to the right) and the envelope of uncertainty for each model are exhibited in [link].



Modeled global temperature values for the standard IPCC fossil fuel scenarios.

Although none of these scenarios is thought to accurately depict the actual future of the world, they do give a reasonable range of behavior options we may adapt in order to mitigate the possible climate change. The model process also provides us with good estimates of the relationship between actual atmospheric carbon dioxide concentrations and resulting expected temperature change. Models also can provide us with information about

changes in other climate factors such as regional changes in precipitation and evapotranspiration, soil moisture, sea surface temperature and acidity, and others, all leading to changes in agricultural productivity, sea level and coastal flooding, public health, species viability and ecosystem health. The top of [link] presents the maximum, minimum and most probable average surface global temperature associated with various atmospheric carbon dioxide levels. The bottom part of [link] then relates these temperature changes to various observable impacts in the form of arrows starting out yellow at temperatures associated with small effects to red at temperatures at which the effects become severe. For example, the first food effect starts with minor falling crop yields in some regions at about 1.5°C temperature change to severe crop failures at temperature changes over 5°C. Scenarios A1T or B2 are the most optimistic scenarios considered. They both show a modest increase in carbon dioxide emission peaking around 2040 and coming back to current levels by 2100 ([link]). Even under these “best cases”, the atmospheric concentration by 2100 will have reached a value of approximately 550 parts per million ([link]) and the temperature change due to the addition of these gases will have reached about 2.5°C (4.5°F) with an uncertainty of ±0.8°C ([link]). The worse case scenario considered is represented by A1F1. This scenario is essentially “business as usual” or no significant changes from current energy practices. In this scenario, carbon dioxide emission reaches over 28 billion tons of carbon (102 tons of carbon dioxide equivalents) per year ([link]) with an atmospheric carbon dioxide concentration over 900 parts per million ([link]). The model temperature rise predicted for the year 2100 by this scenario is 4.5°C (8.1°F) ([link]). This scenario is where we are currently headed and is completely unacceptable. [link] shows what kind of a world we can expect. The Amazon rainforest is gone, hurricanes have increased in intensity, crop yields are down, sea level threatens coastal cities, and there is a possibility of passing the tipping point to a large-scale abrupt climate change.



Examples of impacts associated with various projected global

atmospheric carbon dioxide concentrations and resulting temperature change (Stern. Sir N. (2006) Stern Review: The Economics of Climate Change).

Q4: What can be done about climate change

Responding to climate change predictions: What if anything can be done about it

Short answer

We have seen that the world's climate is changing, in part at least, because of the anthropogenic emissions of greenhouse gases, primarily carbon dioxide from fossil fuel. Humans have a choice that must be made soon; we will either mitigate the problems of climate change by a massive reduction of greenhouse gas emissions or adapt by changing our life style. Mitigation is the stabilization of the climate by the removal of some or of all the fossil fuel derived atmospheric carbon dioxide from the energy equation. Adaptation is action taken to cope with increased rainfall, higher temperatures, scarce water, and more frequent storms. Adaptation may need to tackle present problems or to anticipate changes in the future, aiming to reduce risk and damage cost-effectively, and perhaps even exploiting potential benefits. Somewhere in the middle of these two alternatives we will find an optimal path. It will depend on many factors and different approaches. Success will require an increase in available technology as well as shifts in the culture of people.

Detailed answer

Some of the ways that we can reduce our emissions of fossil fuel carbon dioxide and mitigate climate change are presented below

Immediately implementable with several tangible benefits

- Increase the efficiency of vehicles and reduce the use of these vehicles.
- Build more energy efficient buildings and equip them with energy efficient appliances.

Available technologies with some added costs

- Increase the efficiency of coal and gas power plants, for example, by combining the production and use of both heat and power.
- Use governmental incentives to improve the efficiency of existing technologies and to develop new clean energy technologies.
- Establish policies such as a carbon tax or carbon cap and trade legislation to reduce and eventually stop the emission of atmospheric carbon dioxide.

Available technologies with some lead time required

- Develop wind, photovoltaic and geothermal power as well as fuel from biomass and other newer technologies.

Potential technologies with decadal or multi-decadal time lines

- Develop and construct new and safe nuclear power plants.
- Continue to develop the technology to capture and sequester carbon in order to continue to use fossil fuel until the above-mentioned sources of renewable energy are developed.
- Encourage the development of new and as yet un-thought of technologies to provide efficient and environmentally neutral energy sources.

The cost estimates of implementing mitigation measures or adapting to climate change vary a great deal. First, scientific knowledge about the physical and ecological damages due to climate change is a work in progress. Scientists have no accurate way to determine how rapidly future GHGs will accumulate in the atmosphere or how sensitive biological systems will be to increases in the concentration of those gases. We do not know at what GHG concentrations “tipping points” or catastrophic climate events may occur. It is difficult to estimate how willing or able people will be to adapt to new climate conditions. Finally it is virtually impossible to put a value on damage that will be incurred in the future.

Various mitigation measures can be divided into two categories: supply and demand. By this categorization I mean that we as consumers demand energy while it is up to business and industry to supply that energy.

The first two measures listed above are primarily demand measures and are based on our individual efficiency and planning in the use of energy. These measures will actually save us money while reducing the consumption of fossil fuels. To give two examples; insulating your home can save up to 2,000 pounds of carbon dioxide and $840 per year. Moving your heater thermostat down two degrees in the winter and up two degrees in the summer can save 2,000 pounds of carbon dioxide and $98 per year. With the introduction of these and other modest energy efficiency practices into our personal lives, we, as a nation, could significantly reduce our carbon dioxide emissions.

Many of the other methods of reducing carbon dioxide emission are macro and require modification of current technology or the development of new technology. The success of these methods will depend upon the will of business and industry to implement them. These will all cost varying amounts of money. The intervention of the governments of the world will be necessary to soften these costs. We as consumers will also need to be willing to support these added costs. Eventually, after a perhaps lengthy transition period, new and more efficient clean energy technologies will generate new jobs and new profits at lower costs to the public.

One government intervention that can be used to control carbon emissions from industrial point sources is a cap and trade program. Such a program operating through the free market will establish a price for carbon reduction. The actual price will depend on the cost of new technology and the refinement of existing methods of energy production. Many details need to be worked out before a suitable structure for a government required structure could be implemented. It may end up as some form of cap and trade or it may take the form of a carbon tax.

The cost of adaptation to climate induced damage on the other hand depends on the costs of increased drought, flooding of coastal cities, effects on agriculture, increased numbers of severe weather events, and other such factors as well as the cost of personal discomfort with changing temperatures. A wide range of uncertainty surrounds any estimate of economic damage from climate change. But the damage and therefore the cost of that damage will increase with increasing temperature change. In the

Stern report, he estimates that the loss in GDP per capita by 2200 under his baseline climate scenario (with relatively high emissions and including market and nonmarket impacts and catastrophic risk) ranges from about 3 percent to 35 percent, with a central estimate of 15 percent. Other studies show that if temperature increases are less than 3°C (from 1990–2000 levels), average losses should be contained at or below 3 percent of world GDP.

One economic problem facing the governments of the world is that the cost of mitigation must be paid for beginning now. It is thus an immediate economic problem while the cost of adaptation may be put off, coming due sometime in the future when it might be incurred by our children and grandchildren. Unfortunately, the beginning of this future may also be as close as the next natural disaster

The social and economic burden of climate change weighs unevenly on the countries of the world. The actual costs of climate change may be spread over the total world, but the costs to an individual will be proportionately less in those countries with high per capita GDP. Even though the 30 developed and rich nations of OECD account for two-thirds of the world’s goods and, in so doing, emit over half of the fossil fuel carbon dioxide the costs of mitigation as well as adaptation fall disproportionately on the emerging and developing economies. . A successful carbon mitigation program will require the cooperation and active involvement of all countries rich and poor. In addition, successful mitigation efforts in the poorer countries of the world will depend a great deal on the transfer of knowledge and equipment from the technologically more advanced OECD countries.

We must also remember that a financial solution does not take into account effects such as personal discomfort, displacement or deaths caused by the increased frequency or intensity of climate induced natural disasters.

Conclusions or What is our will with respect to climate change?

The future of the world cannot be accurately predicted nor can man's influence on the future be known with complete assurance. The role of science can only be to provide an informed perspective on the issue of climate change. Action must come from people operating at every political/economic/social level. Most assuredly, neither mitigation nor adaptation alone can avoid the risks of climate change, but they can work together to delay or minimize those risks. On the positive side, mitigation measures may reap co-benefits in public health, improved technology, new business opportunities, innovative industrial processes, and increased job possibilities. For example, mitigation measures to reduce GHG emissions from energy production may also remove other air pollutants, protecting public health. In addition, the application of renewable energy mitigation methods will certainly create new industries and additional jobs. .

However, delaying emission reductions will only make the adverse impact more severe and harder to reverse when it finally happens. In addition, no single mitigation or adaptation strategy can possibly solve such an immense problem. The amount of carbon dioxide involved is simply too large. Thus, we must consider all of the available mitigation and adaptation options and choose a combination that will maximize success. These are hard and complicated problems and will involve decisions based on knowledge as well as fortitude. But these decisions must be made and operated on now, the future of the world as we know it is at stake.

Additional Readings

More information can be obtained from a variety of sources. The most complete scientific source is probably the *Intergovernmental Panel on Climate Change*. A complete set of links to their publications and instructions for downloading them can be found on the website < http://www.ipcc.ch/>. Other information can be found on the website of the *National Academy of Science* <http://www.nasonline.org/site/Pag eServer>. Additional insight on the costs of climate change may be found in the insurance and climate change website of the Lawrence Berkeley National Laboratory <http://insurance.lbl.gov>. Many books have been written on

climate change. The most readable popular books are *Field Notes from a Catastrophe* by Elizabeth Kolbert and *An Inconvenient Truth* by Al Gore. A very clear and complete textbook on the theory of climate change is *Global Warming, The Hard Science* by L. D. Danny Harvey.